REMARKS

Claims 9-11 are currently active.

Claim 9 has been amended to obviate the rejection under 35 U.S.C. 112.

The Examiner has rejected Claims 9-11 as being unpatentable over JP6-256067 (Shimpo) in view of Litton and Shinoda. Applicants respectfully traverse this rejection.

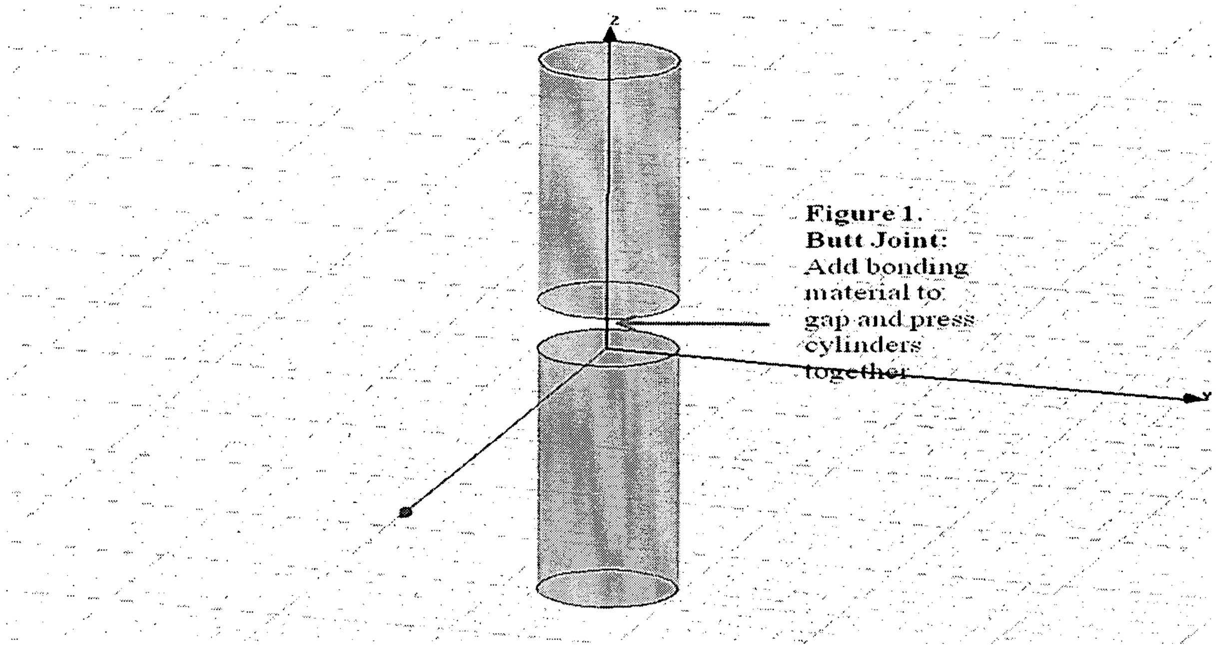
A review of fundamental joint types along with the advantages and disadvantages it is believed will help in the discussions to follow. The joint types that are fundamental to the relevant patents are the butt, lap and taper. Furthermore, a presentation of the formation of porous and weak ceramics from pre-ceramic polymers is also given.

Please see below the references to the text in the parent patent regarding joint thickness, rate of heating and cooling, filler to polymer composition, specific polymer and evacuation and see the modification to the claims in green with parenthesis.

Fundamental Joint Geometries

Butt Joints:

This is simply a joint that is formed by adding bonding material between two parts to be joined and pressing them together, see Figure 1. This is an extremely simple joint that requires very little sample machining or grinding preparation. However, if suffers from lack of control of the joint thickness. Also, the contact area is limited by the area of the cylinder face area.



Lap Joints:

This type of joint is a little more complex than a butt joint in that the inside diameter of the female part must be ground and the outside diameter of the male part must also be ground, see Figure 2. Bonding material can be added to both inside and outside diameters of the ground surfaces, and then the parts are pressed together. The radial gap spacing between the ground surfaces (inside radius of the female part minus the outside radius of the male part) is limited by grinding tolerance for a fired ceramic or limited by machining tolerance of the unfired ceramics. Once the ceramic is fired it may require grinding if there was some differential shrinkage due to either temperature or material differences. Grinding and machining tolerances are controlled by grinding/machining equipment vibration. During the time of Litton (2,972,808) in 1957 machining/grinding tolerances were about one mil=1/1000 inch=25.4 microns, today the machining/grinding tolerances are closer to 0.2 mil~5 microns. Note also that contact area may be increased by increasing the length of the ground surfaces.

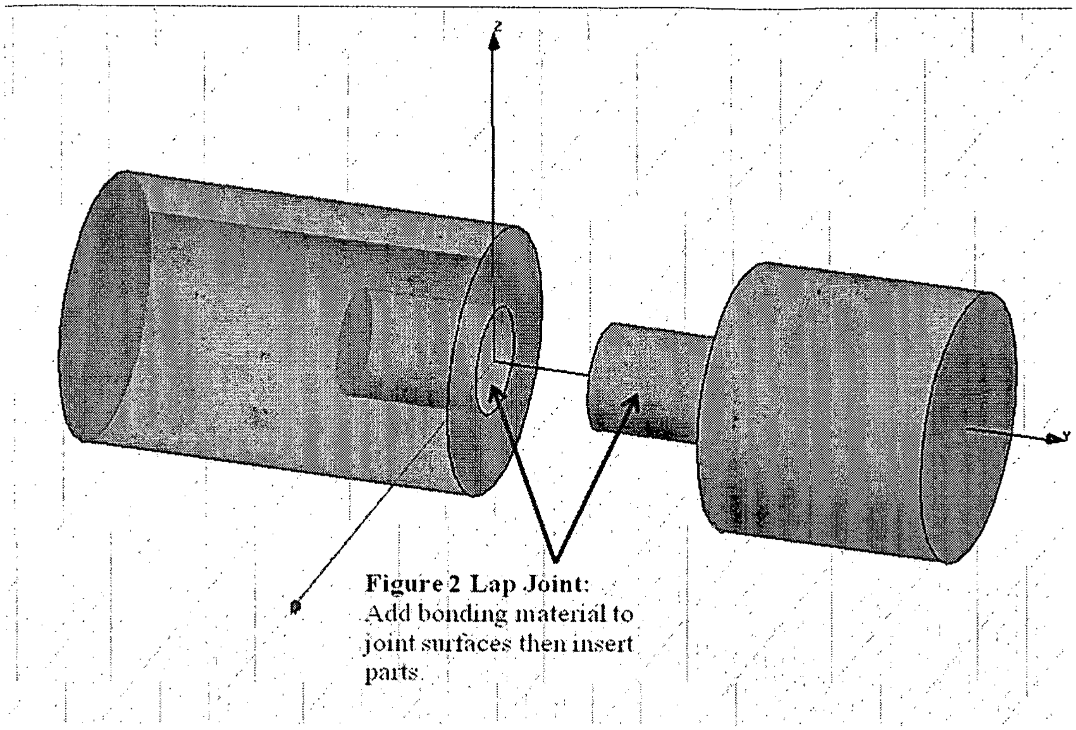


Figure 2 Lap Joint: Add bonding material to joint surfaces then insert parts.

Taper Joints:

This type of joint is a little more complex than a lap joint in that the inside diameter of the female part must be ground and the outside diameter of the male part must also be ground but this time at an angle other than perpendicular to the axes, see Figure 3, let's assume identical angles for now. Bonding material can be added to both inside and outside diameters of the tapered ground surfaces, and then the parts are pressed together. Now the radial gap spacing between the tapered ground surfaces is NOT limited by grinding tolerance for a fired ceramic and NOT limited by machining tolerance for an unfired ceramic. Differential shrinkage will not be an issue if the unfired ceramics come from the same batch of the same material and are fired in a uniform temperature. More contact area can be obtained by using a smaller taper angle. A big advantage of the taper joint is that the radial gap spacing between the tapered surfaces can go to zero if desired, by just inserting one part further into the other as compared to the lap joint.

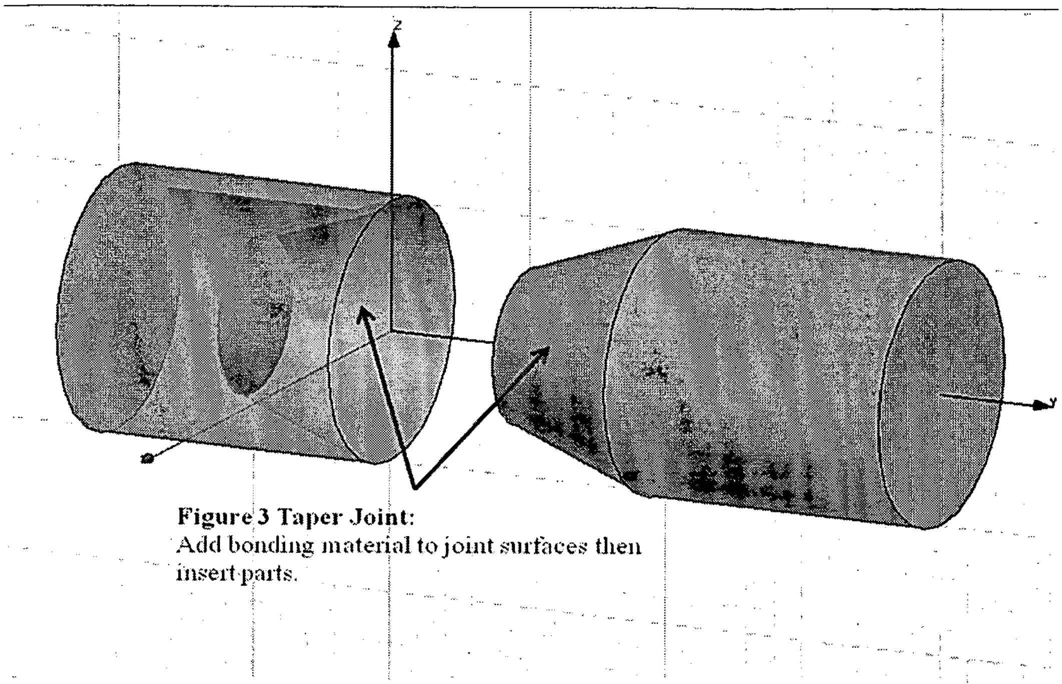
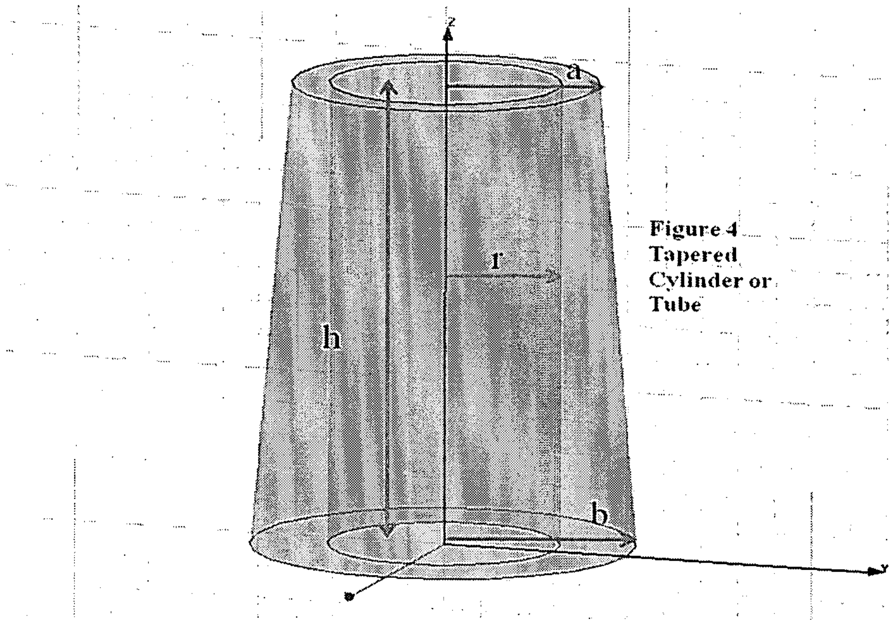


Figure 3 Taper Joint:
Add bonding material to joint surfaces then insert parts.

<u>There are two reasons for tapering when joining cylindrical tubes or rods.</u>

<u>REASON (I)</u> THE TRIVIAL AND OBVIOUS REASON FOR TAPERING IS TO INCREASE THE SURFACE AREA FOR CONTACT COMPARED TO A BUTT JOINT. THE TAPERED CONTACT AREA MAY BE COMPARABLE TO A LAP JOINT.

From Figure 4, this can be quantitatively described for a frustrum of right circular cone tube or cylinder of radii a, b, r (a less than b, r less than a and r is greater than or equal to zero) and height h, the lateral surface area is $A_{cone}=\pi(a+b)[h^2+(b-a)^2]^{0.5}$. To increase the contact area A_{cone} must be greater than $\pi(b^2-r^2)$, where it is assumed that (1) the cylindrical tubes have an outer radius of b and an inner radius of a and (2) the area at the top of the cone, $\pi(a^2-r^2)$, does not make contact with the mating part (although this would just increase the contact area).



REASON (II) A LESS OBVIOUS REASON FOR TAPERING JOINTS IS THAT THE MATING FEMALE AND MALE SURFACES MAY BE BROUGHT ARBITRARILY CLOSE TO EACH OTHER BY SIMPLY INSERTING ONE PART DEEPER INTO THE OTHER (THIS IS ASSUMING IDENTICAL ANGLES FOR BOTH FEMALE AND MALE PARTS). THIS CAN BE USED TO CONTROL THE JOINT THICKNESS AND IS NOT CONSTRAINED BY MACHINING LIMITATIONS.

In the Litton (2,972,808) case, it is absolutely necessary to bring the female tapered cylinder (2,972,808-metal, Fig. 1 part#12) and male tapered cylinder (2,972,808-ceramic, Fig. 1 part#10) surfaces closer together so as to make contact with the metallic interlayer joining material (2,972,808-metal joining alloy, Fig. 1 part#14), otherwise joining may not occur. The metallic interlayer material (joining alloy foil) in Litton is made of 85-95% Copper and 15-5% Nickel to provide ductility, bonding and low RF joint loss (par 6, lines 11-26). This joining alloy foil (Cu-CTE=16.7×10^{-6}/K and Ni-CTE=12.6×10^{-6}/K @ 300K from Material Properties Database v7.37) has a much larger coefficient of thermal expansion (CTE) than either the tapered ceramic cylinder (94% Al_2O_3-CTE=5.8×10^{-6}/K @ 300K from Material Properties Database v7.37) or tapered metal cylinders (Kovar-CTE=5.9×10^{-6}/K @ 300K from Material Properties Database

v7.37) to be joined. The joining alloy foil must be very thin (about one mil=1/1000 inch=25.4 microns, see par 5 lines 72-75) and ductile, so that the joining alloy foil will flex with the joint and not break the bonded ceramic because of large stresses due to the mismatch in CTE. As stated in par 3 lines 24-27 the tapered cylinder parts are closely matched in CTE, in fact the female metal cylinder has a slightly larger CTE than the ceramic cylinder thus keeping the ceramic in compression at room temperature which exploits the strength of the ceramic.

It is still true that more contact area was achieved with a taper compared to a butt joint but this fact contributes little to the success of this type of ceramic to metal joint. To look at this idea of large potential contact area from a different point of view, suppose that we had formed a lap joint, one who's potential contact area is greater than the equivalent taper joint, but with a radial gap all around the circumference of let's say 10 mil and further assume that the end of the male part does not reach the bottom of the female part by say 0.5". Assume the female part is standing vertically (with respect to the center of the earth) and the male part will insert and rest on the top edge of the female part but centered. Now insert our 1 mil thick alloy joining foil at the inside diameter of the female part thus the foil will not make contact with the male part. Upon heating through the melting temperature of the foil the foil will liquefy and flow to the bottom of the female part. The end result of this thought experiment with large potential contact area, but with a large radial gap, is that no joint was formed at all! During 1957 when the Litton (2,972,808) patent was submitted the only way this ceramic to metal joining idea could work is by exploiting the fact that tapers would eliminate the machining tolerance limit (about 1 mil machining limit which is comparable to the joining alloy foil thickness, see Lap Joints above) and allow the mating parts to make contact with the very thin joining alloy foil.

In summary for the Litton (2,972,808) ceramic to metal joining case: (1) to reduce the CTE mismatch stresses between the joining alloy foil and the to be joined approximately matched CTE ceramic and metal parts, the joining alloy foil must be thin (approximately 1/1000 inch) and ductile then (2) to make contact of the thin joining alloy foil with the ceramic on one face and metal on the other face and to overcome machining tolerance limits in 1957 a taper joint must be

used.

Formation of Porous Ceramics from Pre-Ceramic Polymers by Gas Release Resulting in a Weak Ceramic

Before reviewing and critiquing the Shimpo (06-256067) patent a few things need to be stated about the joining of ceramics from pre-ceramic polymers. First we use the terminology pre-ceramic polymers, in this context pre-ceramic polymers are intended to include at least: polycarbosilanes, polysilazanes, hydridopolycarbosilazanes, polycarbosilazanes, polyborosiloxane and allyhydridopolycarbosilane (AHPCS). One of the features of the pre-ceramic polymers that make them desirable for joining is that they are in either a liquid phase or a malleable and/or soluble solid phase at room temperature and can be formed and applied between hard and brittle ceramic parts to be joined. Each pre-ceramic polymer contains the atoms or molecules with the same stoichiometric ratio as the atoms in the ceramic to be joined, in this way there is a close match of the CTE. The idea is to in-situ grow the pre-ceramic polymer into the desired ceramic to be joined. Furthermore, each pre-ceramic polymer contains other atoms or molecules that are not desirable in the final joining state for the ceramics to be joined. These other atoms though provide the flexible (liquid phase or a malleable and/or soluble solid phase) room temperature properties to the pre-ceramic polymer which we don't want in the final fired state. For example, AHPCS is a liquid at room temperature and is rich in the atoms of Silicon (Si) and Carbon (C) with a near perfect stoichiometric ratio of 1:1 in Si:C after firing but has hydrogen (H) atoms and methane (CH_4) molecules that must be removed from the pre-ceramic polymer to form SiC during firing.

It is clear then, that if you want to form for example SiC in a joint you use a polymer that contains atoms of Si, C and other elements or molecules. Upon heating (or other means to break bonds, UV, electrons or ions) all other elements or molecules leave the polymer in a gaseous phase thus what remains are Si and C atoms that form SiC from an atomic phase. If the examiner

is not familiar with this process we have attached a paper entitled "Comprehensive Chemistry of Polycarbosilanes, Polysilazanes and Polycarbosilazanes as Precursors of Ceramics" for his perusal.

The very same mechanism that allows for the formation of a ceramic from the pre-ceramic polymer also has a very undesirable result. When the unwanted gases and/or molecules leave the pre-ceramic polymer voids (flaws) and/or channels are formed leaving the final fired ceramic joint porous. The thicker the ceramic is the larger channels or voids become as the gas leaves the ceramic body. This condition of channel or void growth is analogous to small streams combining to form big rivers, i.e., a small quantity of gas starts at the center of the ceramic then as the gas travels through the volume of the ceramic towards the surface more gas is accumulated hence larger channels or voids are formed. The main consequence of porosity is the joint ceramic is much weaker than a non-porous ceramic joint of the same material. To further establish this point we have added yellow highlighted text from the: "Handbook of Structural Ceramics" by Mel Schwartz, ISBN 0-07-055719-5, McGraw-Hill, 1992.

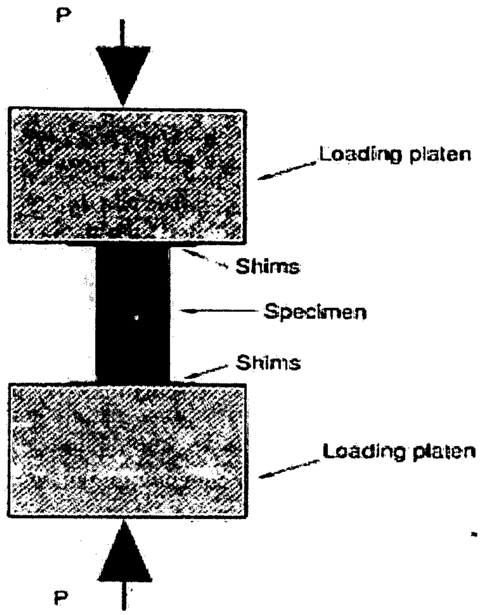


FIGURE 2.7 Schematic of compression test.

perpendicular to the crack plane. The compression tests are conducted on small rectangular or cylindrical specimens whose end surfaces are well machined to have absolutely parallel and flat surfaces. The use of compliant shims between the loading platen and the specimen is also practiced, as shown in Fig. 2.7.

Statistical Analysis

As mentioned previously, the variations in the strength properties of the ceramic necessitate the use of some form of statistical analysis in design. This section will be concerned with a commonly used analysis technique for handling the strength variations in ceramics.

Weibull Analysis. It is recognized that the existence of flaws in materials prevents them from achieving their theoretical maximum strength values. Further, the number of such flaws will depend on the total volume of the material. The greater the volume under stress, the greater the chance of finding the potential strength-limiting flaw. Hence, larger specimens yield lower strengths than smaller specimens, even though material strength, by itself, is invariant, fixed only by the atomic structure and the bond strength of the constituent atoms.

In brittle ceramics, experimental strength results show a definitive relationship between the probability of failure and failure strength.

As mentioned, the strength depends on the shape of the specimen and on the stress distribution dictated by the test methodology used. Nevertheless, the distribution of this property can be analyzed by a Weibull distribution function.

The advantage of using materials having high Weibull moduli, that is, less strength scatter, is readily realized in terms of tensile strengths reasonably close to bend strengths. Another important factor is the necessity to achieve maximum realizable Weibull moduli in products consistent with cost considerations since very high Weibull moduli do not necessarily translate into proportionately higher tensile strengths. These points are illustrated in Fig. 2.8.

It is apparent that as one moves from low-strength materials during the initial stages of new materials development to high-strength materials during advanced stages, the high Weibull modulus also needs to be achieved in order to realize a higher tensile strength, which is of importance in design and application. Also, a Weibull modulus greater than 20 does not result in a significant further increase in tensile strength.

MECHANICAL PROPERTIES OF CERAMICS **2.13**

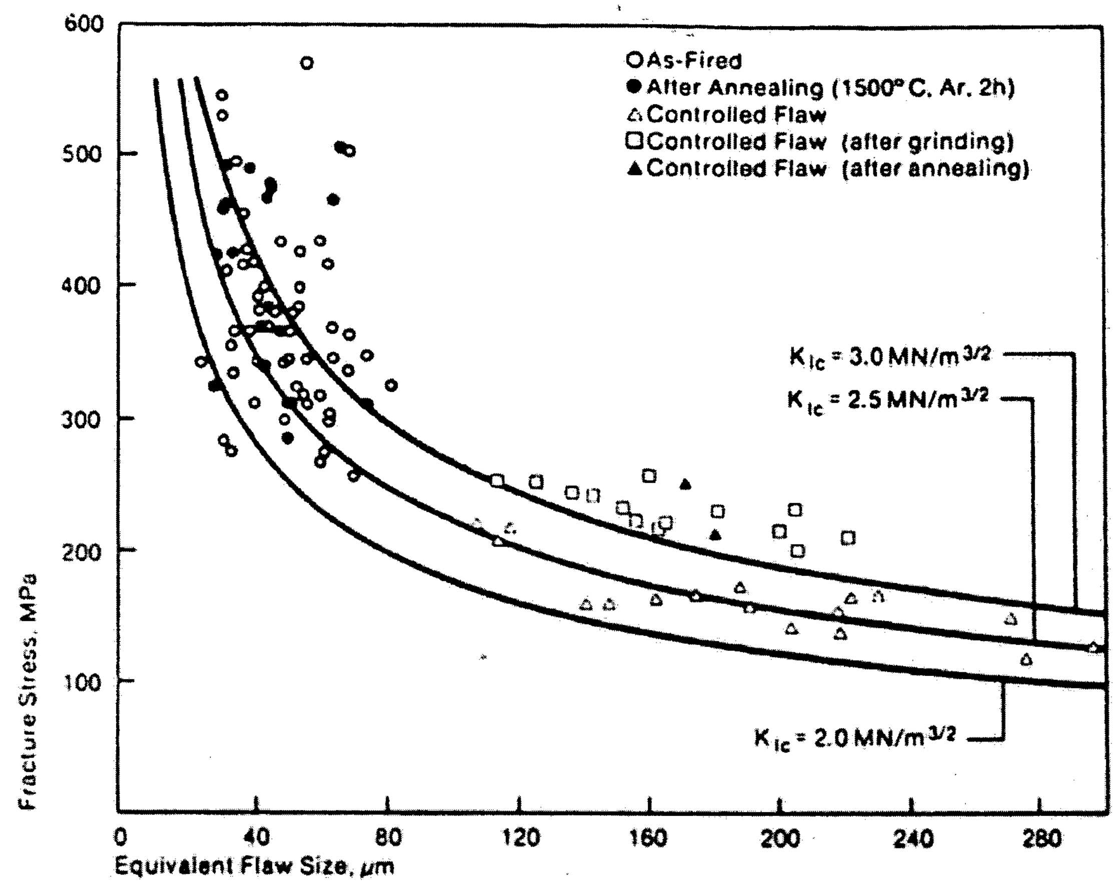


FIGURE 2.11 Effect of flaw size on fracture strength of sintered silicon carbide.

From the same text book (Mel Schwartz) Figure 2.11demonstrates how the flaw size or pore size reduces the ceramic strength in this case the data is for sintered SiC. It is clear that if the joint thickness is less than 250 μm then flaw or pore size will be less than 250 μm in the direction perpendicular to the surfaces to be joined. Further from Figure 2.11 it is clear to form joints smaller than 250 μm will result in higher joint strengths.

During 1993 when the Shimpo (06-256067) patent was submitted the use of polymers to create in-situ parent materials was gaining momentum. However, Shimpo clearly knew about joint porosity (06-256067-page 5, paragraph 10, fifth line from bottom and paragraph 11 third line form bottom) when using polymers. He completely failed to connect joining ceramic porosity

and joint strength with joint thickness in spite of the fact the Mel Schwartz text was published in 1992 and the text data is much older. Furthermore, Shimpo's strongest joints correspond to the weakest fracture stress by comparing Table 1 of Shimpo with a maximum strength of 100MPa to that of Figure 2.11 that has strengths over 500MPa. So how is that there could be a logical, physical or scientific connection to the work of Litton (2,972,808), i.e., why would Shimpo use a taper joint? Litton tried to solve the problem of a mismatch in the CTE of the joining material and Shimpo uses a joining ceramic with a CTE that is matched to the ceramic to be joined (within 1 part in a thousand, pg 6 par 15 lines 6, 14 and 19). The only logical conclusion given the facts that Shimpo is (1) unaware of joint thickness and its effect on joint strength and (2) Shimpo uses materials with a matched CTE then there is absolutely no need to taper the joint to make small joints!

(1) The support for the joint thickness is located at paragraph 4, lines 58-65. See below the text from parent US patent #6,692,597 B2:

The silicon carbide components to be joined are comprised of two silicon carbide tubes and one silicon carbide collar **14**. The silicon carbide tubes are joined together at the tube ends, so the ends should be cut flat to meet. The silicon carbide collar **14** should be machined to fit over both tubes. Less than 0.010" spacing between the outer radius of the tube and the inner radius of the collar **14** produces a stronger joint.

Note: 0.010"=254 microns. Thus 250 microns is approximately 254 microns. Also, it does say less than but should exclude zero thickness joints since one cannot add any bonding material. I suppose this should be obvious.

(2) The support for the atmosphere evacuation is located at paragraph 4, lines 56-57. See below the text from parent US patent #6,692,597 B2:

C. and 1400 degrees C.
The heating is done in an inert environment. Static argon was used during processing.

Note: atmospheric air must be evacuated from the chamber containing the parts to be joined before the environment can be made inert such as with Argon gas.
The viscosity of the polymer is not low enough and contaminating gas adhesion to the polymer is too high at room temperature to remove contaminants after mixing with ceramic additives. Thus, before mixing polymer with additives it is best to evacuate and fill with an inert atmosphere. Further it is best to store polymer and additives in an inert atmosphere. Another obvious thing,

there has to be a chamber containing the parts to be joined, since the alternative is to evacuate the universe which is impossible.

(3) The support for the atmosphere evacuation is located at paragraph 5, lines 34-41. See below the text from parent US patent #6,692,597 B2:

> it. This assembly is placed in a furnace, collar **14** first, and the furnace is put under vacuum for an hour. The vacuum helps outgas the preceramic polymer at room temperature, so that any volatiles trapped in the preceramic polymer will not be left to create porous areas in the joint during heating.
>
> The furnace is then backfilled with argon. A slight argon flow of 2 liters per minute at 1 atmosphere is introduced into the furnace. The tube and collar **14** with slurry **12** is heated

(4) The support for the atmosphere evacuation is located at paragraph 5, lines 55-57. See below the text from parent US patent #6,692,597 B2:

> The furnace is put under vacuum for an hour then backfilled with argon. A slight argon flow of 2 liters per minute of 1 atmosphere is introduced into the furnace. The joint

(5) The support for the atmosphere evacuation is located at paragraph 7, lines 8-11. See below the text from parent US patent #6,692,597 B2:

> coverage on both surfaces of the joint. This butt joint assembly is placed in a furnace and the furnace is put under vacuum for an hour.
>
> The furnace is then backfilled with argon. The butt joint

(6) The support for the atmosphere evacuation is located at paragraph 7, lines 29-42. See below the text from parent US patent #6,692,597 B2:

The slurry **12** is composed of a preceramic polymer and filler material and is prepared in an inert atmosphere, such as argon. First, the filler material is prepared by mixing 90% by weight, 7 micron alpha silicon carbide powder with 10% by weight, less than 1 micron alpha silicon carbide powder. 60% wt filler material is then mixed with 40% by weight allylhydridopolycarbosilane (AHPCS), the preceramic polymer. The slurry **12** has the consistency of a thick paste and is applied using a flat toothpick to the edges of the dovetail joints to be joined. Both composite plates are fit together using the machined dovetail joints and placed in a furnace under vacuum for 1 hour. The furnace is then backfilled with argon. A slight argon flow of 2 liters per minute at 1 atm is introduced into the furnace. The plates are heated at 2° C.

(7) The support for the atmosphere evacuation is located at paragraph 6, lines 60-62. See below the text from parent US patent #6,692,597 B2:

The bonding slurry **12** is composed of a preceramic polymer and filler material and is prepared in an inert atmosphere, such as Ar. The filler material is prepared

(8) The support for the atmosphere evacuation is located at paragraph 4 line 66-67 to paragraph 5 line 1. See below the text from parent US patent #6,692,597 B2:

joint.

The slurry **12** is composed of a preceramic polymer and filler material and is prepared in an inert atmosphere, such

5

as Argon. First, the filler material is prepared by mixing 90%

(9) The support for the heating and cooling rates are located at paragraph 4 line 45-55, paragraph 5 line 41-46, and paragraph 7 line 12-20. See below the text from parent US patent #6,692,597 B2:

Assemble the joint and heat to a temperature of 1400 degrees C.

The heating rate is important, especially at temperatures below 400 degrees C., because too rapid a heating rate can cause bloating, and produce more porosity. Too high a heating rate can also lead to the development of severe cracks in the pyrolyzing polymer. In the preferred embodiment, we heated the joint at 2–3 degrees per minute between room temperature and 400 degrees C. and at 10–20 degrees a minute between 400 degrees C. and 1400 degrees C.

the furnace. The tube and collar **14** with slurry **12** is heated at 2° C. per minute from room temperature to 400° C. At 400° C., the heating rate is changed to 15° C. per minute to 1400° C. The furnace is held at 1400° C. for 30 minutes. The furnace is then cooled at 20° C. per minute to room temperature. The standoff is removed.

The furnace is then backfilled with argon. The butt joint assembly is heated at 2° C. per minute from room temperature to 400° C. At 400° C., the heating rate is changed to 15° C. per minute to 1330° C., the melting temperature of the active filler material in the bonding slurry **12**. The furnace is held at 1330° C. for 30 minutes. The furnace is then cooled at 5° C. per minute to 1300° C., to solidify the active filler material slowly, then at 20° C. per minute to room temperature.

(10) The support for the specific polymer is located at paragraphs 5 lines 4-6 and paragraph 3 lines 55-58. See below the text from parent US patent #6,692,597 B2:

60% wt filler material is then mixed with 40% by weight allylhydridopolycarbosilane (AHPCS), the preceramic polymer. The slurry **12** has the consistency of a thick paste,

of the bodies **10** during processing. The slurry **12** composed of AHPCS and the bimodal silicon carbide powder, when heated, both joins the silicon carbide bodies **10** and sinters to become a form of silicon carbide itself. There is no contamination introduced for such a joint. If the slurry **12**

(11) The support for the mixing composition is located at paragraph 5 lines 4-6 and paragraph 7 lines 1-3. See below the text from parent US patent #6,692,597 B2:

60% wt filler material is then mixed with 40% by weight allylhydridopolycarbosilane (AHPCS), the preceramic polymer. The slurry **12** has the consistency of a thick paste,

atomic % Si and 16.2 atomic % Ti. 60 wt % filler material is then mixed with 40 wt % allylhydridopolycarbosilane, the preceramic polymer. The slurry **12** has the consistency of a

Combining Litton joining method, which applies to brazing ceramic to metal as described above does not apply to the joining of ceramics to ceramics. Shimpo's compound with no specification on joint thickness produces weak joints in bending strength of 80 MPa at 1200°C whereas in the claimed joint more than 100% increase in bending strength is obtained by proper control of joint thickness.

The patent: Litton 2,972,808 utilizes a brazing alloy (5-15 wt % nickel + 95-85 wt % copper, alloy melting temperatures 1140-1180 °C, respectively) for bonding a ceramic (alumina) (coated will 80-90 wt % tungsten + 10-5 wt % iron +10-5 wt % manganese) to metal (Kovar) to form a taper joint["Analysis of Physiochemical Properties of Copper-Nickel System", Kararov,V.V. etal, Dokl. Phys. Chem, 1992].

Litton 2,972,808 is <u>inherently a different joining process</u> than the claimed invention. In the claimed invention, the joining occurs by growing silicon carbide molecules into a structural ceramic joint which creates a matched thermal expansion coefficient and is chemically inert (oxidation resistant out to 1600 °C).

In the Litton patent, some of the metals (tungsten and copper) will restrict the service temperature to low values (<700°C) due to rapid oxidation in air. Tungsten in air at

1100°C for only 1 hour has been measured; the oxidation rate of 1000 g/m^2. There is almost no tungsten metal left after 1 hour.

Additionally, the thermal expansion coefficient of Kovar is well matched to alumina up to about 550°C, but after 550°C Kovar expands must faster than alumina thus creating joint stresses which further restricts the use of this type of joint [pgs 322-324, Handbook of Electron Tube and Vacuum Techniques, Fred Rosebury, American Institute of Physics 1993].

The motivation of the Litton patent is described in his own words: "Although ceramic-to-metal seals manufactured according to the foregoing process may function satisfactorily the process is carried out carefully, there are several inherent disadvantages which detract from the utility of the process and of the articles formed thereby. Firstly, from the standpoint of the article per se, when the seal is made to the flat end of the ceramic cylinder the seal is frequently weak structurally owing to the fact that its area is limited to the cross-sectional area of the cylinder. Similarly, where the seal is made to the lateral periphery of the cylinder, the seal frequently will leak or form gas traps which subsequently cause failure of the vacuum tube or other device in which it is utilized, one reason for this form of failure being that it is difficult to bring the ceramic and the metal to which it is to be sealed into uniform engagement. From the process standpoint, furthermore, the prior art process set forth hereinabove requires very precise machining of the ceramic and metal parts in order to assure even a reasonably good seal."

It is submitted the Examiner has found the word taper used in one context (namely, brazing ceramic to metals) and has applied that word to a different context (ceramic to ceramic joining). It is important to understand that the reason for a need in one context does not necessarily apply to another context.

There is a fundamental difference as to why one forms a tapered ceramic to metal braze joint (Litton) compared to why one forms a tapered ceramic to ceramic bond joint where bonding is done by as grown ceramic material (claimed invention). For ceramic to metal there is

generally a mismatch in the thermal expansion coefficient between braze material and the ceramic, mismatches as small as 10% create large stresses which can break the ceramic, thus it is necessary to keep the braze material thin so as to plastically deform under the stress. For brazing metal, thin generally means less than or equal to 0.004 inches~100 microns of a malleable braze alloy. **The tapering in a ceramic to metal braze joint provides a uniform area with a thin joint to minimize stress induced by a mismatch in the thermal expansion coefficient (as in Litton).** To look at this differently, if the brazing material and the joining metal had an identical thermal expansion coefficient as the joining ceramic over the entire temperature range of use then both the braze material and the metal to be joined can be arbitrarily thick. That is, no stresses will build up in the ceramic, thus no breakage will occur. This of course is not reality.

Now, in the case of the ceramic to ceramic joint with a joining compound that matches the thermal expansion coefficient of the to be joined ceramics, as is the case in the claimed invention, one might conclude that the joint material could be arbitrarily thick. This would be exactly wrong. The reason being is the thicker the bonding ceramic is the larger are the voids that are formed, larger voids makes a weaker ceramic bonding material thus weaker joints when bonding ceramic to ceramic. Void formation is an inherent process when producing the bonding material. That is bonding material starts out as a malleable solid or a liquid made up of, in the simplest case, atoms of silicon, carbon and hydrogen. This joining material is for example bonding silicon carbide ceramic to silicon carbide ceramic. When this compound is heated correctly, just the hydrogen is removed from the compound, leaving behind pure silicon carbide which grows into crystals that bond together the silicon carbide ceramic to silicon carbide ceramic. What results when the mass of hydrogen is liberated from the joining compound are voids where the hydrogen was previously located. Furthermore, the pure silicon carbide joining material is a solid that cannot flow to fill the voids. The size of the void space can range from 10-60 % of the dimensions of the bonding material. This range of void size is controlled by the heating rate. By keeping the absolute value of the joint thickness small (less than 0.01 inches~250 microns), then the voids will be small, hence a stronger bond will be formed. The tapering in a ceramic to ceramic joint with the same ceramic for bonding provides

a uniform area with a thin joint to maximize joint strength by reducing the size of the voids (as in the claimed invention).

It is respectfully submitted Shinoda does not add anything in relevant part to Litton and Shimpo to arrive at applicants' claimed invention.

Accordingly, Claim 9 is patentable over the applied art of record. Claims 10 and 11 are dependent to Claim 9 and are patentable for the reasons Claim 9 is patentable.

In view of the foregoing remarks, it is respectfully requested that the outstanding rejections and objections to this application be reconsidered and withdrawn, and Claims 9-11, now in this application be allowed.

Respectfully submitted,

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